REMARKS

OVERVIEW

Claims 1-13 are pending in this application. Claims 11-13 are new. The present response is an earnest effort to place all claims in proper form for immediate allowance.

INFORMATION DISCLOSURE STATEMENT

The Examiner indicates that the Examiner did not receive a copy of the item titled "New Z-Based . . . Performance". It is observed that the present application is a Divisional Application and this reference was provided in the parent application. To assist the Examiner, however, a copy of this item is being provided. It is asked that the Examiner properly consider this publication and indicate that it has been considered by initialing the item in the Information Disclosure Statement previously filed by the Applicant.

ISSUES UNDER 35 U.S.C. § 112

Claims 1-10 have been rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicant regards as the invention. In particular, the Examiner indicates the use of the term "about" renders the claims indefinite. It is respectfully submitted that one of ordinary skill in the art would be reasonably apprised of the scope of the invention as the term "about" is used to mean slightly above or slightly below. It is also submitted that the Examiner mischaracterizes the claims as ones where it would be appropriate to apply MPEP 2173.05(b). Here the rationale

of MPEP 2173.05(b) does not apply as the claimed invention is distinct from the prior art for the reasons later expressed herein.

ISSUES UNDER 35 U.S.C. § 102

Claims 1-9 have been rejected under 35 U.S.C. § 102(b) as being anticipated by or, in the alternative, under 35 U.S.C. § 103(a) as obvious over U. S. Patent No. 4,677,413 to Zandman. This rejection is respectfully traversed.

Claim 1 explicitly requires "a first resistive foil having a low TCR of about 0.1 to about 1 ppm/°C." Zandman does not explicitly disclose this limitation. The Examiner appears to recognize this fact but indicates that this limitation is disclosed by Figures 2 or 5. It is respectfully submitted that if the Examiner further examines Figures 2 and 5 they do not directly illustrate TCR, but rather show ΔR/R in ppm and temperature in degrees Celsius. The TCR could, however, be computed by the quotient of ΔR/R and temperature. It is further observed, however, that neither Figure 2 nor Figure 5 includes a scale for ΔR/R therefore it is unclear how the Examiner can purport to determine TCR based on these Figures. Therefore, it is respectfully submitted that this limitation is not disclosed as the Examiner indicates and this rejection must be withdrawn.

Claim 1 also requires "a first resistive foil, pattern, and substrate being selected to provide a cumulative effect of reduction of resistance change due to power." It is respectfully submitted that this limitation makes the prior art remote and the Examiner has not properly considered this limitation. What the Examiner overlooks is that Zandman '413 does not disclose consideration of the effect of these parameters together to provide a **cumulative effect** of reduction of resistance change **due to power** as required by the claim. By improperly ignoring this limitation,

the Examiner is ignoring the structure implied by the process steps. Note that in the present case, ranges are provided for each of the parameters. Therefore, even if a prior art reference was to disclose a parameter within the range of parameters or an overlapping range this limitation would not be met unless the resistive foil, pattern, and substrate were selected to provide a cumulative effect of reduction of resistance change due to power. As described in the Specification, the present invention looks not at independently manipulating these parameters but rather at considering a cumulative effect provided by these parameters not disclosed in the prior art. Therefore, this rejection must be withdrawn for this independent reason. As claims 2-10 depend from claim 1, it is respectfully submitted that these rejections should also be withdrawn.

Claim 10 has been rejected under 35 U.S.C. § 103(a) as being unpatentable over Zandman '413 in view of Witt et al. The differences of Zandman '413 have already been described and therefore this rejection should be withdrawn on this basis.

NEW CLAIMS

Claim 11 is supported by the Specification, at least at page 1, lines 11-13.

Claim 12 is supported by the Specification, at least at page 4, lines 8-16.

Claim 13 is supported by the Specification, at least at page 4, lines 3-6 as well as page 1, lines 11-13. It is respectfully submitted that the statement "The resistor can get hot and yet it will show only very small changes in resistance due to power" supports the statement that "an operating temperature for the resistor is greater than ambient temperature." Thus, there is no new matter.

CONCLUSION

No fees or extensions of time are believed to be due in connection with this amendment; however, consider this a request for any extension inadvertently omitted, and charge any additional fees to Deposit Account No. 26-0084.

Reconsideration and allowance is respectfully requested.

Respectfully submitted,

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Enclosure

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New Z-Based Foil Technology Enhances Resistor Performance

Reuven Goldstein and Joseph Szwarc
Vishay Intertechnology, Inc.

The production of high-precision resistors depends primarily on the degree of control maintained over the effects of temperature on device resistance. Although manufacturers have mastered the effects of changes in ambient temperature, correction for the Joule effect—in which a resistor heats up and dissipates power as a result of the load it is handling—remains a challenge. By significantly reducing the sensitivity of resistors to changes in applied power, a new "Z-based" foil technology from Vishay Intertechnology provides as much as a tenfold improvement in wattage coefficient of resistance (WCR), a key figure of merit for resistors that accounts for the effects of both ambient temperature change and resistor self-heating. Resistors based on this breakthrough Z-based technology offer the same form and fit function as do conventional devices, while establishing a greatly improved standard for accuracy in fixed resistor applications such as feedback, gain setting, voltage division, and current sensing

in a wide range of end products.

Understanding Temperature and Wattage Coefficients of Resistance

When influenced by the Joule effect (a rise in temperature due to self-heating), low-TCR resistors tend not to perform to their TCR specifications. Inaccuracy in high-precision resistors with TCR values of just a few ppm/°C can result in untenable error in the estimate of the resistor's stability under load. This problem makes it difficult for designers to choose the best resistor for a given application.

Understanding and addressing the effects of temperature change in relation to self-heating requires a new figure of merit—a power coefficient of resistance. This figure is referred to as the wattage coefficient of resistance (WCR) for better phonetic differentiation from temperature coefficient of resistance (TCR). By considering these TCR and WCR figures independently, designers can better evaluate resistors according to the demands of their system designs.

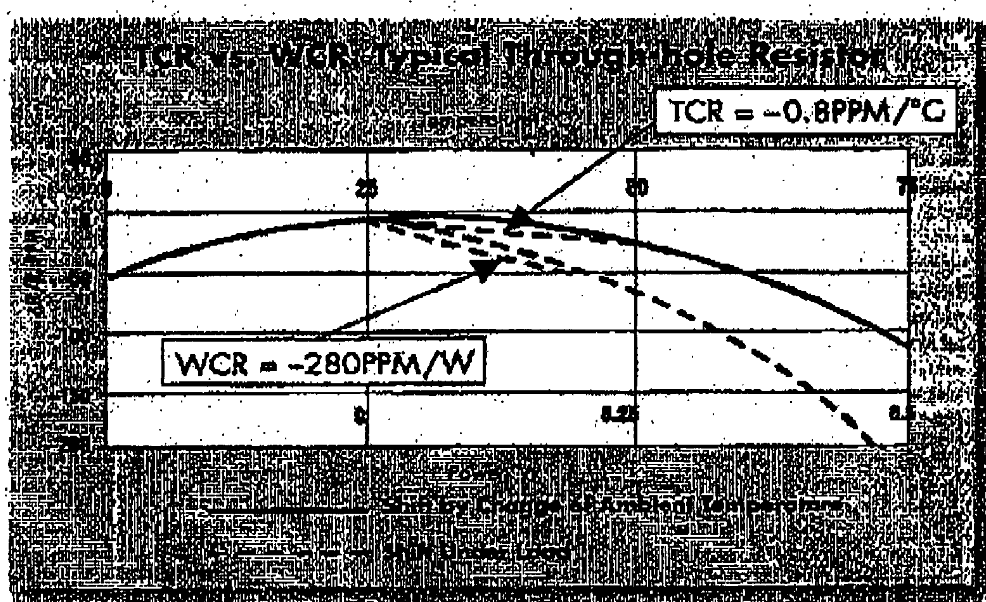

Figure 1

If the current level is constant but the ambient temperature is variable, then a resistor with a low TCR value will offer the greatest stability. If, on the other hand, the current level is variable but the ambient temperature is constant, then high stability can be provided by a resistor with a low WCR value. Finally, if both the current level and ambient temperature are variable, a resistor with low TCR and WCR values will offer the best stability.

Measuring the Effects of Self-heating and Determining WCR

Using a thermally similar model with a resistive material of high TCR, such as a Balco alloy of 5,000 ppm/°C, it is possible to measure the temperature rise of the resistive layer as a result of self-heating.

First, the DC resistance value (R) at different temperatures (T) is measured to establish the relationship between resistance change and temperature, R = f(T). As voltage (V) and current (I) then are measured at stabilized levels up to rated power, the established R = f(T) relationship may be used to translate the power (VI) and resistance (V/I) into temperature. This calculation generally will provide more useful and accurate results than a temperature sensor placed near the resistive layer. Though results may be similar, the latter method fails to indicate either the average temperature of the resistive layer or a reliable measurement of its actual temperature.

Manufacturers often use this method to determine the proportional relationship between power load and temperature rise in a particular resistor and, in turn, to establish a value of thermal resistance (R_{th}) in °C/W for the device. What this test does not account for is heat transfer via conduction from the resistor's outer surface and through the leads and PCB. Because the extent of heat transfer depends on mounting method, substrate, PCB construction, and pad and trace sizes, so too does the R_{th} of a device.

For the sake of accuracy in these tests, the R_{th} must be referred to the environment to account for the wattage directed to areas other than the resistive layer and the body/heat sink. Manufacturers often assume that the temperature for the PCB or outer surface will remain stable (at ambient temperature); as a result,

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their measurements may not reflect the true thermal resistance of the device.

To determine WCR when TCR is not the key figure, first assume α to be the coefficient of thermal expansion of the substrate material. Next, evaluate the strain under load in a foil chip under a rise in ambient temperature against the strain under self-heating. A change in ambient temperature (ΔT_a) will cause a strain (ε_a) in the substrate ($\varepsilon_a = \alpha \cdot \Delta T_a$). This strain makes up for the increase in resistance of the heated foil; however, if the foil's temperature rises by the same ΔT_1 because of the heat generated by a load (P), the strain will not be the same. A part of the load's heat [$P_s = f_1 \cdot P$ ($f_1 < 1$)] will be directed normally toward the substrate.

Assuming a uniform distribution of power on the chip's surface, the thermal resistance of the foil/substrate interface (R_{thf}) will cause a temperature drop of $\Delta T_i = P_s \cdot R_{thf}$ and the strain in the substrate's top surface will be reduced by $\varepsilon_i = \alpha \cdot \Delta T_i$. Within the substrate, due to its thermal resistance (R_{ths}), the temperature will drop further by $\Delta T_s = P_s \cdot R_{ths}$. For a plate that can expand, a linear temperature drop across its thickness (t) causes a difference in expansion between the top and the bottom surfaces (a strain difference between surfaces $\varepsilon_{bs} = \alpha \cdot \Delta T_s$), and the plate bends into a spherical shape of radius $r = t/(\alpha \cdot \Delta T_s)$.

This effect may be constrained by external forces in a resistor chip. For example, when a chip is attached to a heat sink, the substrate is not free to expand. Thermal stresses may be due to nonuniform distribution of the power on the chip's surface, because the heat-generating part of the foil doesn't cover the whole substrate and some of the heat flows in other than the normal direction. These conditions may modify the strain. As a result, the strain in the substrate's top surface will be further reduced by ε_{tg} (smaller than the ε_{bs} of bottom surface) by a factor f_g, with $f_g < 1$: $\varepsilon_{tg} = f_g \cdot \alpha \cdot \Delta T_s$.

The total difference in the strain for the same temperature in the substrate's top surface, because of change in ambient temperature versus self heating, will be $\varepsilon_i + \varepsilon_{tg} = \alpha \cdot \Delta T_i + f_g \cdot \alpha \cdot \Delta T_s = \alpha \cdot P_s (R_{thf} + f_g \cdot R_{ths})$.

When the resistive foil is forced to follow the strain in the substrate's top surface, the relationship between

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the relative resistance change and strain is expressed by gage factor k; in this case k = 2. As a result, a resistor of zero TCR will show, under load P, a loss in value [$\Delta R/R = 2\alpha \cdot f_1 P(R_{th1} + f_2 \cdot R_{th2})$], and its wattage coefficient of resistance will be $WCR = (\Delta R/R)/P = 2\alpha \cdot f_1(R_{th1} + f_2 \cdot R_{th2})$.

Improvements in Low-WCR Resistors

Tailor-made solutions now address the demand for precision resistors with high stability, even under changing load levels. Low-WCR resistors have been designed to meet custom specifications for variations in ambient temperature, load changes over time, limits of allowed resistance

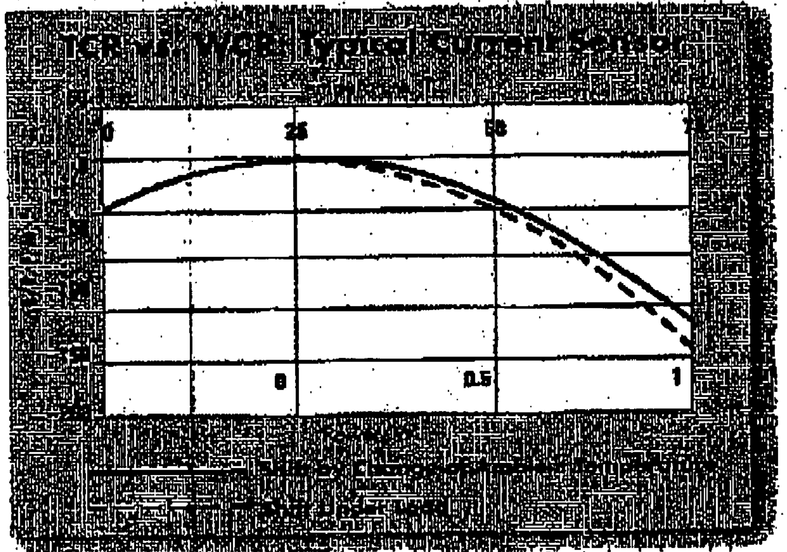

Figure 2

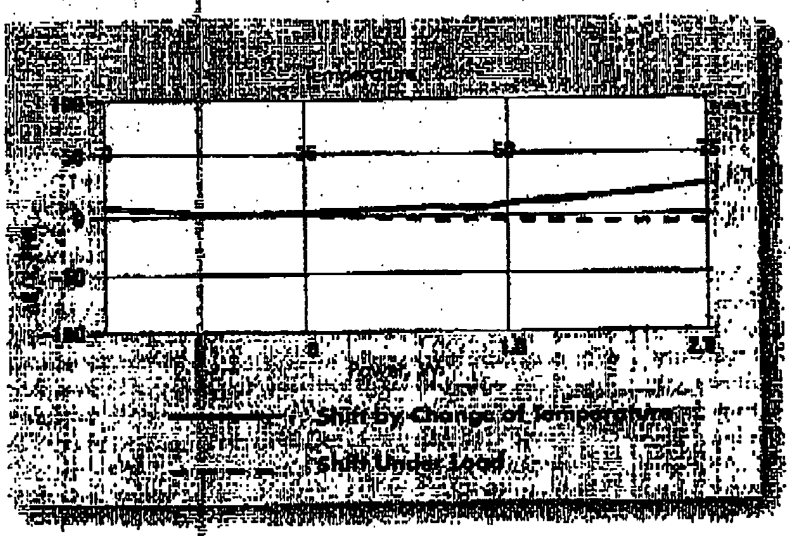

Figure 3

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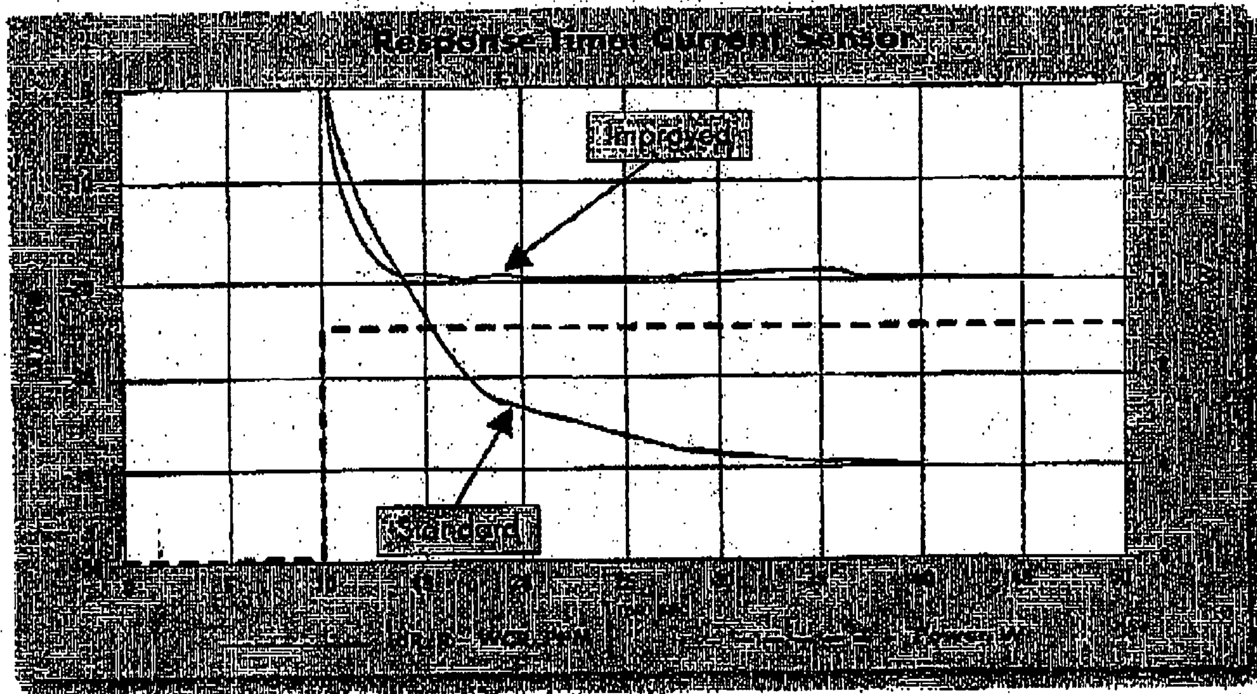

Figure 4

change, and time it takes to reach resistance limits following a particular change in load.

One such resistor—Vishay's 0.3-W, standard through-hole resistor—shows a slope of −0.8 ppm/°C TCR over a temperature range from 25°C to 50°C. With an R_{th} of 100°C/W and a WCR of 280 ppm/W, the same foil's temperature rise due to self-heating results in a slope of 2.8 ppm/°C (Figure 1).

Figure 2 illustrates a current-sensing resistor (Vishay style VCS332) rated at 3 W in air and 10 W on a heat sink (at 25°C ambient), engineered for low TCR at room temperature. The same style of resistor engineered for best combination of TCR and WCR is shown in Figure 3. Figure 4 shows the response of a VCS332 heat-sink-mounted current sensor to a step pulse of 10 W. In this case, the thermal time constant was improved by a factor of 3.

A higher level of performance is possible with Vishay's introduction of the Z-foil resistor, which offers TCR levels previously unheard of in a single chip device. The use of Z foil in power resistors and current-sensing resistors with low TCR and low thermal resistance allows for much improved current measurement because the change in resistance with current changes has been reduced radically. Likewise, the performance of surface-mount chip resistors could be taken to new levels with the implementation of Z-foil technology. There are numerous possibilities for the use of this breakthrough technology in the development of ancillary products.

Conclusion

A resistor's WCR is affected directly by the way in which the resistor has been mounted, particularly if surface- or heat-sink-mounted; as a result, data from device manufacturers is insufficient to determine an accurate WCR value. Likewise, a high-precision resistor's stability is influenced directly by temperature—the resistor behaving differently when heated by an outside source, as opposed to self-heating while dissipating its own power. Quantifying this difference within the resistor's specifications can contribute significantly to the stability of the device.

Designers working with specifications for stability of just several ppm/°C should test for stability under changing load to ensure satisfactory performance under conditions matching the application in question. For applications requiring high stability under changing load conditions, resistors of low WCR should be specified. For constant loads and variable ambient temperatures, low-TCR resistors will provide the best stability. And when both ambient and wattage are variable, both low TCR and WCR are required to ensure high stability. Designers now can guarantee a new degree of stability and accuracy in fixed-resistor applications using solutions based on Vishay's revolutionary Z-based resistor foil technology. ☐

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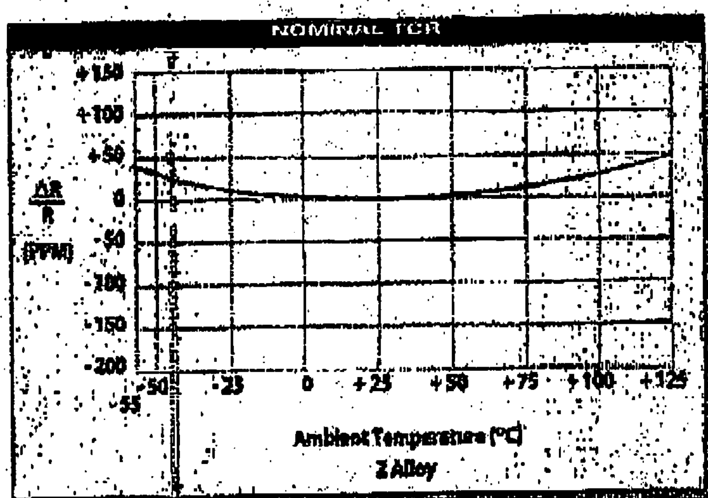
BREAKTHROUGH

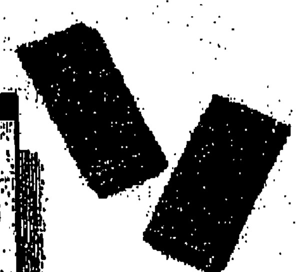
from VISHAY INTERTECHNOLOGY

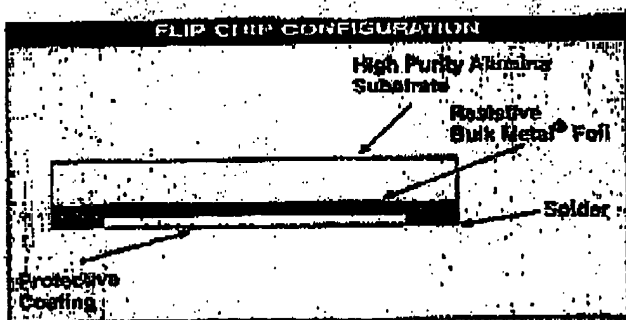
0.15ppm/°C (0°C to 60°C) TCR
HIGH PRECISION FLIP CHIP RESISTOR
VFC1506: Bulk Metal® Foil Technology



- Lowest TCR, using Z Foil Technology:
  0.15ppm/°C (0°C to 60°C)
  0.5ppm/°C (-55°C to +125°C)
- Tolerance to: 0.01%
- Non-Inductive (< 3nH)
- 50% higher power capability over standard surface mount chips

0805, 1206 SIZES AVAILABLE SOON





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